A PROCEDURE FOR EDITING FLIGHT DYNAMIC DATA USING A COMBINATION OF DIGITAL PROCESSING AND MANUAL REMOVAL OF ELECTRICAL NOISE SPIKES

Harry Himelblau
MS 301-456
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109-8099
(818) 354-8564

A procedure is described for the separation of electrical noise spikes from random vibroacoustic measurements in order to obtain a valid estimate of maximax flight spectra. This procedure is applied to noise-contaminated data obtained from a Titan IV payload fairing (PLF) internal acoustic measurement.

INTRODUCTION

Environmental flight data from an expendable launch vehicle are usually acquired using telemetry transmission from the vehicle to one or more ground stations. The reception is usually good, providing high quality signals for subsequently recording. Occasionally electrical noise "spikes", sometimes called data dropouts or "click" noise, occur during mission events or time periods when flight data are most needed, i.e., when the environment is a maximum. Often these spikes are caused by interference problems between the telemetry transmitter and receiver. When this occurs, considerable effort may be devoted to removing noise effects if the value of the environmental data makes the effort worthwhile. The editing of dynamic data to remove the effects of a variety of electrical noise sources is discussed in [1].

A step-by-step procedure has been developed for the removal of noise spikes from both random vibration and aeroacoustic flight measurements. These environments are usually nonstationary. In most cases, a measurement is used to establish a maximax spectrum, i.e., the maximum spectral value for each frequency band of the spectrum independent of when each maximum occurred during a mission event [2]. The major reasons for utilizing the maximax spectrum is to obtain conservative design and test criteria, and to enable its implementation in a stationary laboratory test.

An example has been selected to illustrate the data editing procedure. This example, shown in Figure 1, occurred during liftoff of a Titan IV launch vehicle, when the acoustic environment inside the PLF reached its maximum [3, 4]. Figure 1 shows an exceptionally severe occurrence of electrical noise spikes in the wideband instantaneous pressure vs time history. Over 60 positive and negative suspected noise spikes can be observed in this figure between solid rocket motor (SRM) ignition at T + O and the nominal end of the liftoff event at about T + 12 sec. When such a large number of anomalies are observed within the limited duration of a mission event, there is an obvious concern that not enough of the dynamic data will remain to permit its desired utilization. Liftoff vibroacoustic data are generally wideband. The frequency range of the measurement shown in Figure 1 is 20 Hz to 2 kHz. However, the noise spikes appearing in the figure may or may not affect the entire spectrum. The following procedure describes how a combination of digital data processing and manual editing may be used to delete the effects of electrical noise spikes from the desired data signal over the entire spectrum of interest.

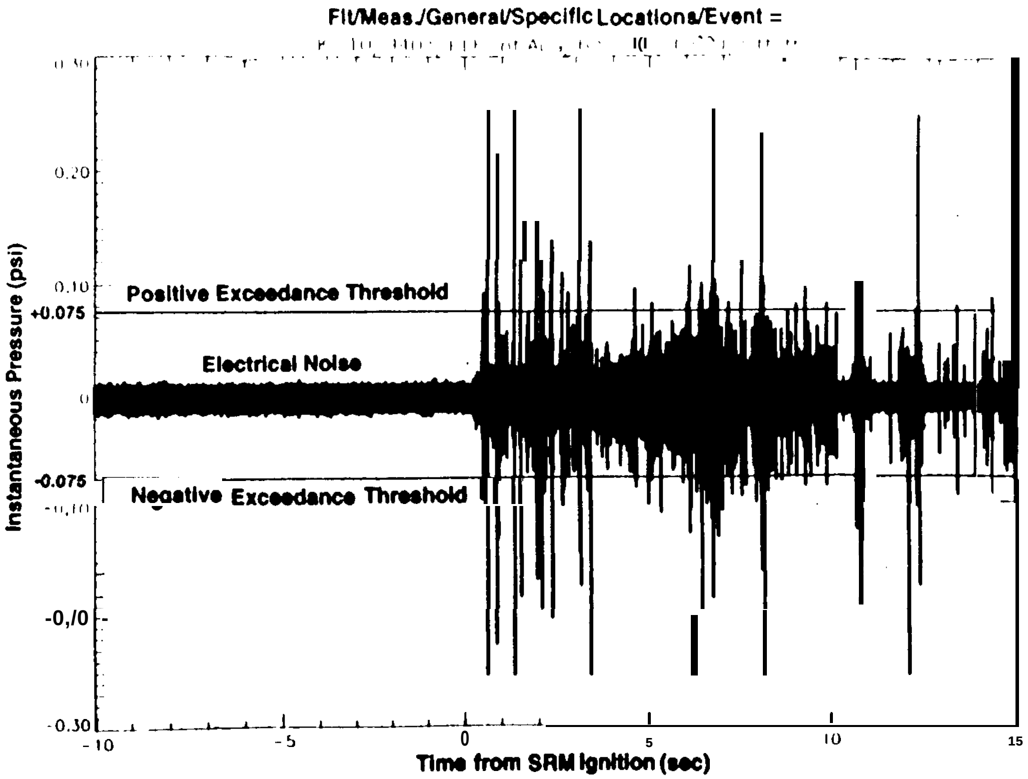

Figure 1. Wideband Instantaneous Pressure Time History for a Flight Acoustic Measurement (2'0 **Hz-2kHz)**

RECOMMENDED DATA EDITING PROCEDURE

The following procedure is recommended for removing the effects of suspected electrical noise spikes from flight dynamic data. To assist in understanding the details, the above-mentioned example will be used to illustrate each applicable step of the procedure.

1. Obtain a digital time history (DTH) of the instantaneous wideband signal for the duration of each critical mission event (e.g., liftoff, max q, stage separation, appendage deployment, engine ignition or shutdown) including any electrical noise such as described in Reference 1. If the instantaneous time history is in an original analog format, convert it to a DTH using ananalog-to-digital converter (ADC), a word size compatible with the minimum acceptable dynamic range (approximately 12 bits for noise-contaminated data), and a sampling rate at least 10 times greater than the highest frequency of interest.

2. Do not artificially clip the instantaneous positive or negative peaks of the DTH, even if the data acquisition system has previously done so.

3. Preserve the original time code (e.g., IRIG-B) used by the data acquisition system, If no time code was used, provide a new one having a sampling rate or frequency response at least 10 times greater than the highest frequency of interest.

4. Examine the DTH for evidence of electrical noise spikes, such as shown in Figure 1, or other anomalies listed in [1]. Note in Figure 1 the occurrence of true data dropouts between T + 10.2 and 10.7, and between T + 11.0 and 11.9 sec.

5. If there is evidence of noise spikes, select positive and negative exceedance thresholds, such as shown in Figure 1 at ±0.075 psi, which will assist in the separation of these spikes from the desired data signal. (If the signal is random, the thresholds should be about 4 times the maximum rms value of the signal.) For highly nonstationary or transient data, time-dependent thresholds may be preferred,

6. Program the digital software to identify the magnitudes and times of occurrence of positive and negative peaks that exceed these thresholds. Make a tabular listing of the peak value and time of each threshold exceedance, preferably taken in chronological order. Carefully examine the peaks that barely exceed the thresholds. Delete those peaks from the tabulation that appear to be random signal peaks rather than noise spikes. For example, there appears to be several random peaks in Figure 1 between T + 5.5 and 7.5 sec that barely exceed the thresholds.

7. Obtain short time-averaged wideband and narrowband rms time histories, or overall (OA) and 1/3 octave band (1/3 OB) sound pressure level (SPL) THs, to observe variations caused by both noise spikes and the random data signal. Figures 2-5 show OA and typical 1/3 OB SPL THs for the DTH of Figure 1 using T_{ave} = 0.1 see, found to be "ideal" for these observations.

8. Using the tabulated listing of each peak value and time of occurrence of Step 6, identify which 0.1 sec interval in an rms or SPL TH might <u>possibly</u> be contaminated by noise spikes. For example, these contamination zones are shown by vertical bars in the OA SPL TH of Figure 2.

9. Compare the rms or SPL value in each contamination zone with the random rms or SPL variations outside of these zones.

10. Delete the rms or SPL value in any contamination zone if that value exceeds the observed random variations, <u>assuming</u> the exceedance is due to noise spike(s). If the value is not exceeded, <u>assume</u> that noise spikes have no measurable effect. In Figure 2, <u>excessive</u> noise spike contamination is observed to occur@ in the following 0.1 sec intervals: T + 0.6, 1.3, 2.3, 3.1, 3.4, 8.1 and 10.8 sec. Note that no excessive contamination is observed during the 1 sec period between T + 6 and T + 7 sec when the maximum OA SPL = 134.5 dB is reached.

11. Repeat Steps 8-10 for each narrowband (NB) rms or 1/3 OB SPL TH, concentrating mainly on contamination zones which occur during the l sec period when the maximum NB rrns or 1/3 OB SPL is reached, such as shown in Figures 3-5. (It has been observed that excessive contamination intervals for a particular NB rms or 1/3 OB SPL TH will <u>seldom</u> coincide with the excessive contamination intervals found in the OA rms or SPL TH or in another NB rms or 1/3 OB SPL TH.)

12. Once excessively-contaminated NB rms or 1/3 OB SPL values are deleted from each TH, determine the maximum rms or SPL, averaged over a 1 sec period, for each band.

13, For each band, compare the maximum rms value or SPL with the prelaunch rms value or SPL. If the indicated maximum does <u>not</u> exceed the prelaunch value by at least 10 dB, apply a correction for the effects of electrical noise floor using Figure 6 [1]. If the difference between the indicated maximum and the noise floor is 3 dB or less, the true maximum is equal to or less than the noise floor, In this case, it is recommended that the data be discarded since there is no accurate method of estimating the true maximum value. In Figure 5, the difference between the indicated maximum 1/3 OB SPL and prelaunch noise floor is (112.5 - 106) = 6.5 dB. Figure 6 shows that 1 dB should be subtracted from the indicated maximum to obtain the true maximum 1/3 OB SPL = 111.5 dB. For Figure 2-4, the differences exceed 10 dB, so no correction is required.

14. Once this procedure is applied to each band, square each NB rms value and divide by the bandwidth. Then collect the various maximum mean square or SPL values to form the maximax spectrum for the measurement.

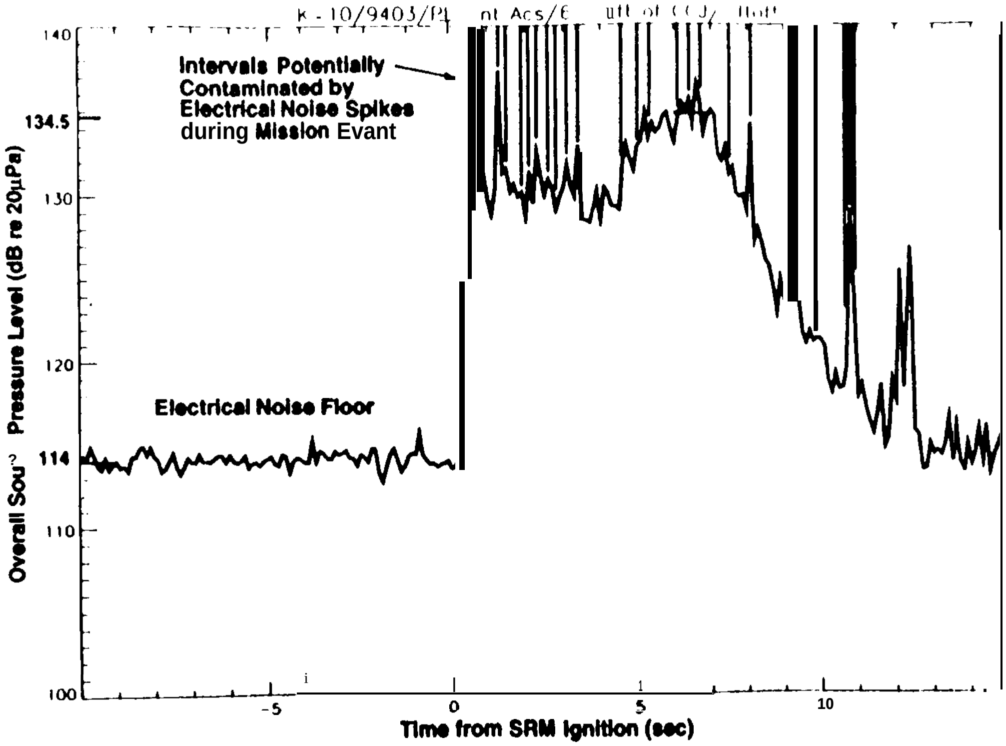

Figure 2. Overall Sound Pressure Level Time History for a Flight Acoustic Measurement (T_{ave}=0.1 sec)

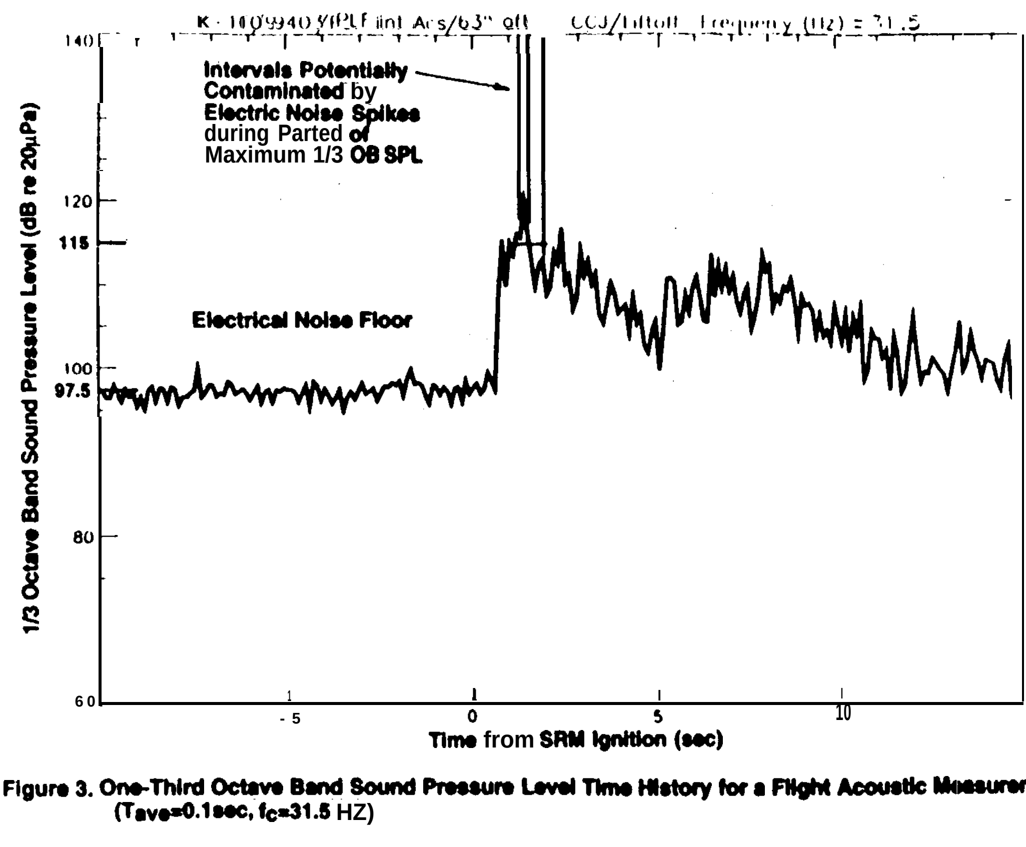

Figure 3. One-Third Octave Band Sound Pressure Level Time History for a Flight Acoustic Measurement (T_{ave}=0.1sec, f_c=31.5 HZ)

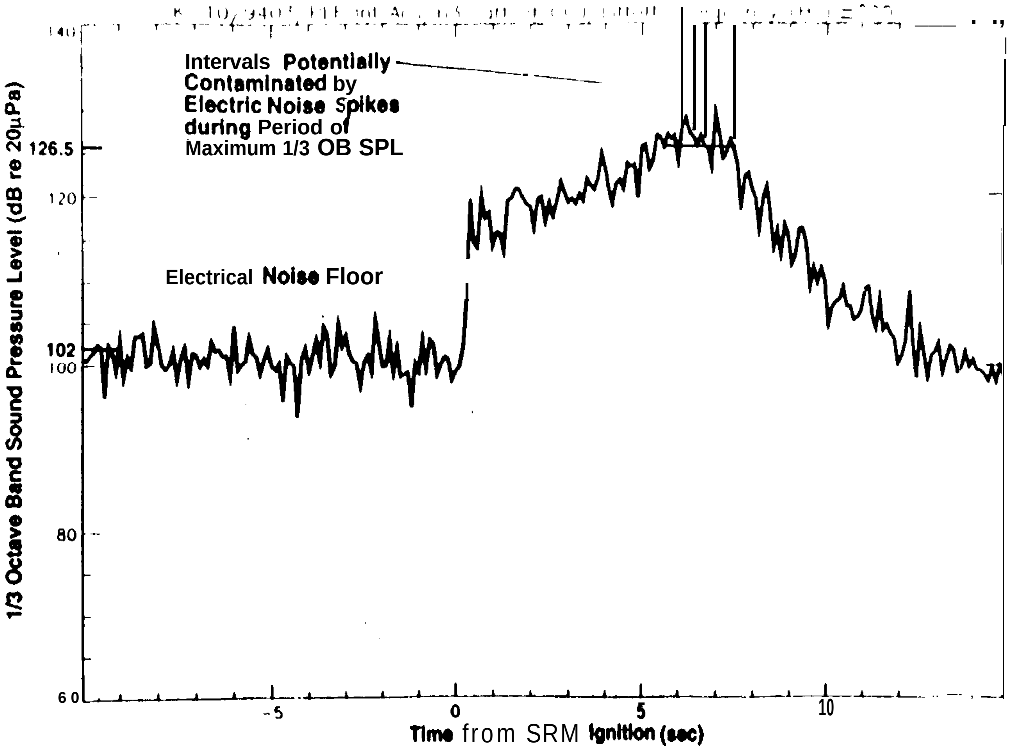

Figure 4. One-Third Octave Bond Sound Pressure Level Time History for a Flight Acoustic Measurement (T_{ave}=0.1sec, f_c=200 Hz)

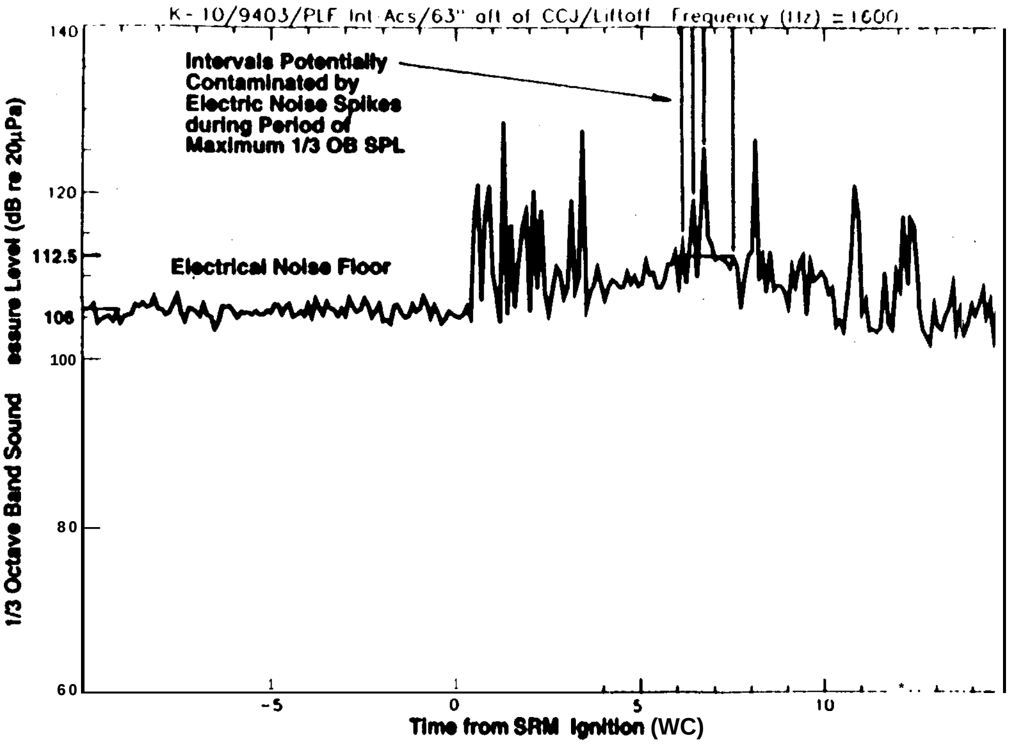

Figure S. One-Third Octave Band Sound Pressure Level Time History for a Flight Acoustic Measurement (T_{ave}=0.1sec, f_c=1.6 kHz)

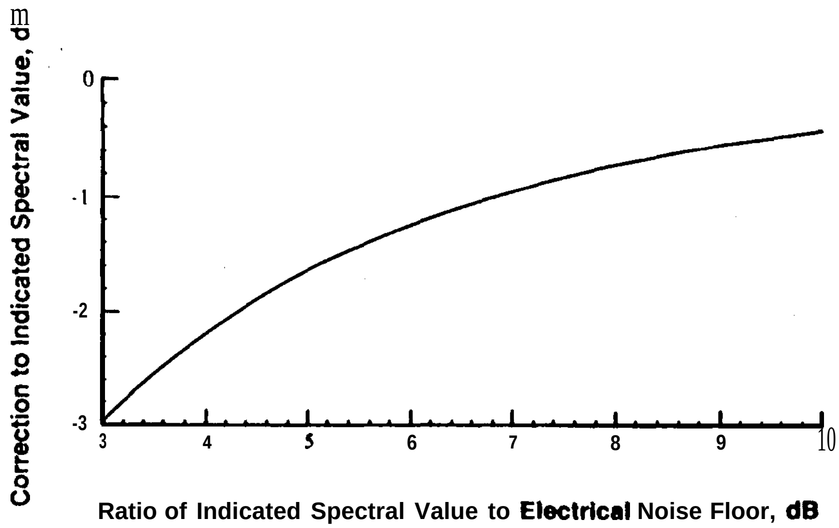

Figure 6. Noise Floor Correction to the Spectral Estimate of a Random Signal

CONCLUSIONS

The recommended procedure has been effective in removing electrical noise spikes from flight random signals used for establishing maximax spectra and design and test criteria. For example, Figure 7 shows a spectral comparison of unedited and edited data for the acoustic measurement of Figure 1, However, this procedure can be very labor-intensive when there is a large number of noise spikes.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support provided by J. E. Phillips and C, S. Tanner of The Aerospace Corporation, L. Bradford and A. C. Boone of Martin Marietta Technologies, A. G, Piersol of Piersol Engineering Company, and D. L. Kern and A. R. Hoffman of JPL. The research described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

REFERENCES

1. Himelblau, H., Piersol, A. G., Wise, J, H. and Grundvig, M. R. May 1994. "Handbook for Dynamic Data Acquisition and Analysis," Inst. Envir. Sci. Recommended Practice DTE 012.1, sec. 4.

2. Ref. 1, App. B.

3. Himelblau, H., Kern, D. L. and Davis, G, L, May 1992."Development of Cassini Acoustic Criteria Using Titan IV Flight Data," Proc., Inst. Envir. Sci. ATM, 2:307-331.

4. Himelblau, H., Kern, D. L. and Davis, G. L. Sept./Ott. 1993.''Summary of Cassini Acoustic Criteria Development Using Titan IV Flight Data," J. Inst. Envir. Sci., XXXVI (5): 19-27.

5. Ref. 1, Sec. 3.

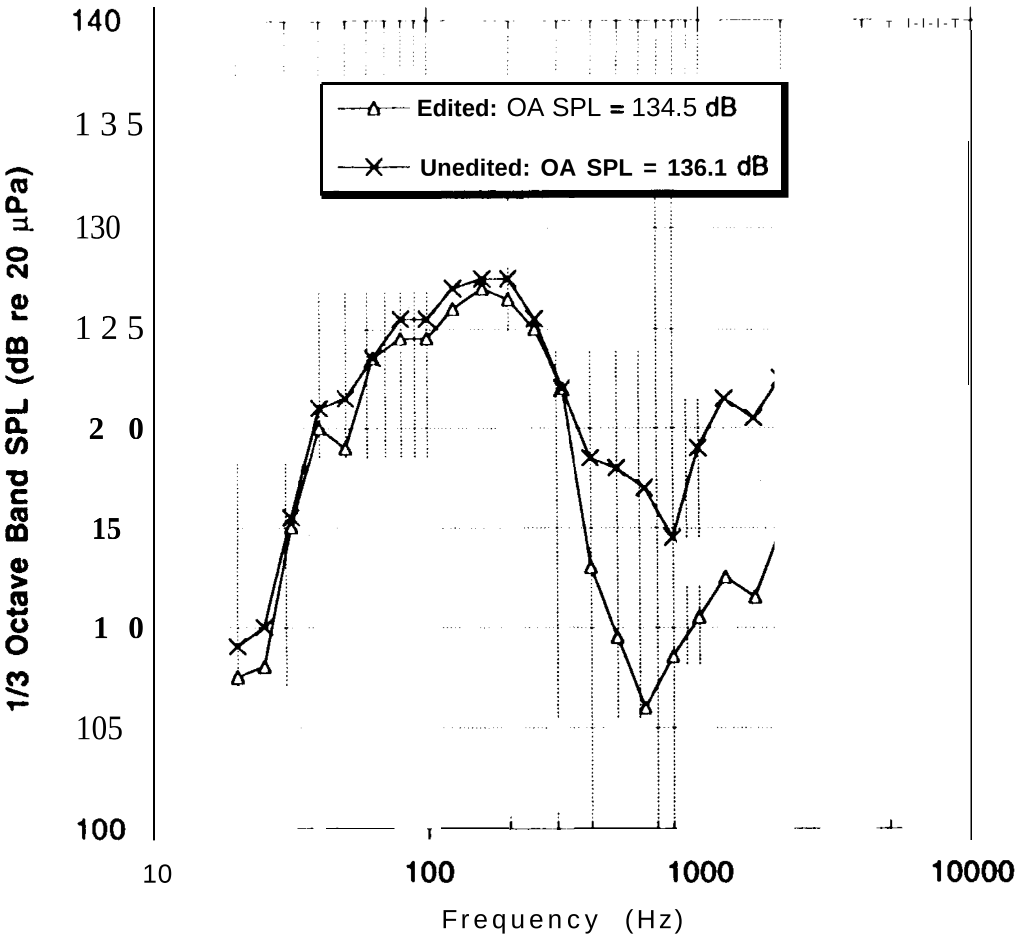

Figure 7. Comparison of Edited and Unedited Maximax Spectra for Acoustic Measurement Shown in Figure 1.